Real Exchange Rate and Consumption Fluctuations following Trade Liberalization*

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Abstract

Two-sector models with traded and non-traded goods have problems accounting for the stylized fact that the real exchange rate appreciates and consumption booms for several years following trade liberalization, or exchange-rate-based stabilization programs, in small open economies. The paper investigates some possible solutions to this 'price-consumption puzzle' and evaluates their quantitative importance in calibrated simulations of Spain's accession to the European Community in 1986. Extending the standard two-sector framework, the paper investigates the effects of relative productivity growth in the traded sector along the lines of Balassa-Samuelson, of time-to-build, and of habit formation in preferences. The analysis shows that a calibrated version of the augmented model can account for more of the price-consumption dynamics after trade liberalization than a benchmark two-sector model, without losing explanatory power for other real variables in the Spanish economy after 1986.

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1 Introduction

It is a well documented empirical regularity that the real exchange rate appreciates and consumption booms for several years following trade liberalization or exchange-rate-based stabilization programs in small open economies (Végh (1992) and Uribe (2002)). Two-sector models with traded and non-traded goods that have often been used to analyze such episodes have problems accounting for these stylized facts, as pointed out by Uribe (2002). Typically in these models, the real exchange rate appreciates in the first period of the liberalization or stabilization program and then counterfactually depreciates, while the consumption of non-traded goods increases over time. A class of widely used models thus fails to replicate the observed co-movement between the real exchange rate and consumption.

The paper investigates some possible solutions to this 'price-consumption puzzle', and evaluates their quantitative importance in calibrated simulations of Spain's accession to the European Community in 1986. Extending the two-sector framework of Fernandez de Cordoba and Kehoe (2000), the paper investigates the effects of relative productivity growth in the traded sector along the lines of Balassa-Samuelson, of gestation lags in investment, and of habit formation in preferences.

In the two-sector growth model which we subsequently develop, higher productivity growth in the traded sector makes non-traded goods relatively more expensive to produce over time, as suggested by Balassa (1964) and Samuelson (1964), which implies that the real exchange rate appreciates in the long run. Uribe (1997) shows that gestation lags in investment, combined with convex capital adjustment costs, lead to a gradually increasing investment demand in the initial phase after a positive and permanent shock in a small open economy. Therefore, time-to-build has the potential of making the real exchange rate gradually increase after trade liberalization. Following Uribe (2002), we introduce habit formation in preferences, since it has the potential of causing the consumption of both traded and non-traded goods to increase over time, although the real exchange rate is appreciating in the model.

Ultimately, it is a quantitative question whether the investigated mechanisms are really of importance for improving the model's capacity to replicate the co-movement of the real exchange rate and consumption. Therefore, the paper makes a serious attempt at calibrating habit formation and gestation lags in the model and measuring the relative productivity developments for Spain and Germany through sectoral growth accounting.

The analysis shows that a calibrated version of the augmented model can account for more of the price-consumption dynamics after trade liberalization than the benchmark two-sector model. The magnitudes of the fluctuations in the real exchange rate and consumption improve considerably when relative productivity growth, time-to-build and habit formation are incorporated in the model. The augmented model cannot fully account for the observed co-movement of the real exchange rate and consumption in Spain, but in several periods, the model real exchange rate appreciates while the consumption of both traded and non-traded goods increases. We also show that, except for the trade balance, the augmented model does not lose explanatory power for other real variables in the Spanish economy after 1986.

We next take a look at the data for the real exchange rate and consumption in Spain after 1986. Section 3 develops, calibrates and simulates the basic model, which is similar to the model developed by Fernandez de Cordoba and Kehoe (2000) and will serve as a benchmark for the analysis in the paper. The simulations of the basic model demonstrate the weakness of the standard two-sector framework in the price-consumption dimension. In section 4, we analyze the qualitative effects of introducing higher productivity growth in the traded sector, time-to-build, and habit formation in preferences. Section 5 explains how we calibrate the augmented model and in section 6, we investigate the quantitative relevance of the three mechanisms when simulating the model. The concluding remarks are presented in section 7.

2 The real exchange rate and consumption in Spain after 1986

After joining the European Community, Spain experienced large capital inflows associated with a sustained appreciation of its real exchange rate and a consumption boom. These initial effects of trade liberalization are similar to the effects of the well-documented exchange-rate-based stabilization plans undertaken by several Latin American countries. Uribe (2002) documents the effects of the Argentine convertibility plan of 1991 and identifies a 'price-consumption regularity' in that in the initial phase, the real exchange rate gradually appreciates while the consumption of both traded and non-traded goods increases over time. Végh (1992) and Kiguel and Liviatan (1992) provide extensive evidence on this stylized fact concerning the real exchange rate and consumption for other Latin American countries.

In figure 1, rer is the log of the bilateral real exchange rate between Spain and Germany for the years 1986-2002. In the model that we develop in section 3, there is only one traded good and no nominal variables. Therefore, the model can only account for the part of real exchange rate fluctuations that is due to changes in the the relative price of non-traded to tradable goods. Following Fernandez de Cordoba and Kehoe (2000) and Betts and Kehoe (2001), we decompose the real exchange rate into its traded and non-traded components,

$$RER_t = S_t \frac{P^G_{Tt}}{P^S_{Tt}} * \frac{P^G_t}{P^S_t} \frac{P^S_{Tt}}{P^G_{Tt}} \quad (1)$$

$$RER_t = RER_{Tt} * RER_{Nt,} \quad (2)$$

where S_t stands for the nominal exchange rate expressed in units of pesetas per DM, P^G_t is a price index for Germany, P^S_t is price index for Spain and P_{Tt} is a price index for tradable goods.

In equation (2), RER_{Tt} captures relative price changes of traded goods, whereas RER_{Nt} captures relative price changes of non-traded goods. Expressing equation (2) in logarithms, we obtain

$$rer_t = rer_{Tt} + rer_{Nt}. \quad (3)$$

The model assumes Purchasing Power Parity to hold for traded goods, which implies that $rer_{Tt} = 0, \forall t$ and that fluctuations in the real exchange rate can only be caused by movements in the relative price of non-traded goods across countries. When constructing price indices for traded goods, we use Producer Price Indices for the manufacturing sector in each country.[1] The details and the sources of the data are given in Appendix A.

The log of the non-traded component of the real exchange rate, rer_N, is presented together with the log of the real exchange rate in Figure 1. The fact that rer_N appreciates over time means that the relative price of non-traded goods increased faster in Spain than in Germany between 1986 and 2002. The figure reveals a strong co-movement between the two series, with the non-traded component explaining almost two thirds of the gradual appreciation of the real exchange rate up to the currency crisis in 1992.

Figure 2 shows the development of real consumption of traded and non-traded goods in Spain for the years 1986-1998, which grew over the period, with a stronger initial boom in traded consumption. Traded and non-traded goods are defined as in Fernandez de Cordoba and Kehoe (2000). Agriculture and the manufacturing industry constitute the traded sector whereas construction and services for sale constitute the non-traded sector. For details on how we obtain the sectoral consumption data in figure 2, see Appendix A.

Figures 1 and 2 together reveal that the stylized facts concerning the 'price-consumption regularity' apply to Spain after 1986. Following trade liberalization, the real exchange rate and the relative price of non-traded goods gradually appreciated for several years, while aggregate consumption and its non-traded component boomed. The remainder of the paper will therefore try to develop a model that can account for the dynamics of the non-traded component of the real exchange rate, and its co-movement with consumption of both traded and non-traded goods.

[1] For a more detailed discussion of the suitablility of PPI as a measure of price changes for traded goods, see Betts and Kehoe (2001) and Engel (1999).

3 The basic model

The starting point of the analysis in this paper is a model which is representative of the class of two-sector models often used to analyze the effects of trade liberalization or exchange-rate-based stabilization (see Rebelo and Végh (1995) for a survey). In this section, we present a model to which we will refer as the basic model, which is similar to that used in Fernandez de Cordoba and Kehoe (2000). The basic model will provide a benchmark against which to evaluate the quantitative relevance of the mechanisms investigated in the paper for improving the model dynamics for the real exchange rate and consumption.

Spain is modeled as a small open economy with a representative consumer. In the basic model, there are five goods in any period: a traded good, a non-traded good, capital, labor and an investment good augmenting the capital stock in the subsequent period. The traded good is the numeraire in the economy.

The centralized problem consists of maximizing the sum of discounted utility from consumption of traded and non-traded goods, subject to the resource constraints of the economy:

$$\max_{\{c_{Tt},c_{Nt},k_{Tt},k_{Nt},b_{t+1},l_{Tt},x_{Tt},x_{Nt}\}} \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{\sigma}-1}{\sigma}\right], \tag{4}$$

where the consumption of traded and non-traded goods, c_{Tt} and c_{Nt}, constitutes aggregate consumption, c_t, according to

$$\begin{aligned} c_t &= C(c_{Tt}, c_{Nt}) \\ &= \left[\varepsilon c_{Tt}^{\rho} + (1-\varepsilon)\, c_{Nt}^{\rho}\right]^{\frac{1}{\rho}}. \end{aligned} \tag{5}$$

The maximization is subject to the following constraints

$$c_{Nt} + x_{Nt} \leq F_N(k_{Nt}, k_{Nt-1}, l_{Nt}, l_{Nt-1}) \tag{6}$$

$$c_{Tt} + x_{Tt} + b_{t+1} - b_t(1+r) \leq F_T(k_{Tt}, k_{Tt-1}, l_{Tt}, l_{Tt-1}) \tag{7}$$

$$(k_{Tt+1} + k_{Nt+1}) - (1-\delta)(k_{Tt} + k_{Nt}) \leq G x_{Tt}^{\gamma} x_{Nt}^{1-\gamma} \tag{8}$$

$$L = l_{Tt} + l_{Nt}, \tag{9}$$

$$c_{Tt}, c_{Nt}, k_{Tt}, k_{Nt}, l_{Tt}, x_{Tt}, x_{Nt} \geq 0 \quad \forall t$$

$$k_{T0}, k_{N0}, l_{T0}, l_{N0}, b_0 \text{ given,}$$

where (6) is the economy's resource constraint for non-traded goods and x_{Nt} is the input of non-traded goods into the investment technology specified on the right-hand side of (8). Note that the production process for non-traded goods, $F_N(.)$, is a function of inputs of capital and labor into the non-traded sector, k_N and l_N, in both the current and the previous period. Output depends on lagged factors of production, due to costs associated with frictions in capital and labor mobility.

The resource constraint for traded goods, (7), includes additional terms that reflect the possibility of trading with the rest of the world; b_{t+1} denotes a foreign bond purchased in period t and redeemed in period $t+1$ at the world interest rate r, which we assume to equal $1/\beta - 1$.

The law of motion for capital is specified in (8). Investment goods are produced using a Cobb-Douglas technology taking traded and non-traded goods as inputs. The model assumes that labor is supplied inelastically, as specified in equation (9), where L is the size of the total labor force.

The utility function exhibits a constant intertemporal elasticity of substitution, which equals $1/(1-\sigma)$, and a constant intratemporal elasticity of substitution, $1/(1-\rho)$. The parameter ε determines relative preferences for traded and non-traded goods, and β is a subjective discount rate.

The production processes are modeled in the following way

$$F_T(k_{Tt}, k_{Tt-1}, l_{Tt}, l_{Tt-1}) = A_T k_{Tt}^{\alpha_T} l_{Tt}^{1-\alpha_T} - \Phi(k_{Tt}, k_{Tt-1}) - \Psi(l_{Tt}, l_{Tt-1}) \tag{10}$$

$$F_N(k_{Nt}, k_{Nt-1}, l_{Nt}, l_{Nt-1}) = A_N k_{Nt}^{\alpha_N} l_{Nt}^{1-\alpha_N} - \Phi(k_{Nt}, k_{Nt-1}) - \Psi(l_{Nt}, l_{Nt-1}), \tag{11}$$

where for $j \in \{T, N\}$

$$\Phi(k_{jt}, k_{jt-1}) = \frac{\zeta}{1+\zeta} \left(\frac{|k_{jt} - (1-\delta)k_{jt-1}|}{k_{jt-1}} \right)^{\frac{1+\zeta}{\zeta}} k_{jt-1}, \quad \zeta > 0 \tag{12}$$

$$\Psi(l_{jt}, l_{jt-1}) = \psi \left(\frac{l_{jt} - l_{jt-1}}{l_{jt-1}} \right)^2 l_{jt-1}, \quad \psi > 0. \tag{13}$$

Here, $\Phi(.)$ is a convex adjustment cost associated with investment, as in Abel and Eberly (1994) and Eberly (1997). Note that the specification in (12) implies that capital frictions are present in steady state, because the cost is associated with the transformation of investment goods rather than the adjustment of the capital stock. $\Psi(.)$ is a quadratic cost associated with the adjustment of the labor force in a sector. The specification implies that there are costs of both hiring and firing when labor moves between sectors. It is in the specification of the factor frictions that the basic model differs from the model in Fernandez de Cordoba and Kehoe (2000). The reason is that the functional forms in equations (12) and (13) are easier to calibrate than the frictions used by Fernandez de Cordoba and Kehoe (2000).

The solution to the centralized problem in (4) corresponds to a decentralized equilibrium where a representative consumer maximizes utility and where firms in the traded, non-traded and investment sectors maximize their profits under perfect competition.

3.1 Calibration of the basic model

To facilitate a comparison between the models used in this paper and the existing literature, the basic model is calibrated as closely as possible to Fernandez de Cordoba and Kehoe (2000). We normalize all prices except the rental price of capital to be 1 in 1986, and use the equilibrium conditions of the model to find the values of the parameters and the initial conditions. Germany, the largest economy in the EC in 1986, will in the paper be used as a proxy for the 'rest of the world' in the small open economy setting.

Aggregating the input-output table for Spain in 1986 under the assumption that Spain was closed to capital flows in 1986, Fernandez de Cordoba and Kehoe calculate values for the parameters ε, γ and G, as well as the sectoral division of output in 1986, y_{T0} and y_{N0}.[2] The initial capital-output ratio is taken from the Penn World Table, where the capital stock estimate includes nonresidential capital, residential construction and transportation equipment. A period is assumed to be a year, and the values of σ, ρ, β and δ are chosen to be identical to the values used in Fernandez de Cordoba and Kehoe (2000).

Eberly (1997) has estimated the convex component of capital frictions of the form specified in (12), using annual data for the OECD countries between 1981-1994. For Spain, we use a value of $\zeta = 1.6133$, which is an average of the values Eberly estimates for France, Germany and the UK. These three countries are the only ones in Europe for which Eberly obtains statistically significant estimates, with values of ζ ranging from 1.29 for Germany to 1.95 for France.

In order to obtain $k_{T0}, k_{N0,}l_{T0,}l_{N0}, \alpha_T, \alpha_N, A_T$ and A_N, we solve a system of eight equations provided by the equilibrium conditions of the model for the autarky steady state in equations (14)-(17). First, note that the output in sector j, where $j = \{T, N\}$, in the last year before liberalization is

$$y_{j0} = A_j k_{j0}^{\alpha_j} l_{j0}^{1-\alpha_j} - \frac{\zeta}{1+\zeta} \delta^{\frac{1+\zeta}{\zeta}} k_{j0}, \tag{14}$$

where the last term is the cost associated with the transformation of investment goods into capital. Next, we use the fact that in equilibrium, capital in each sector earns its marginal product, which implies that

$$y_{j0} X_j = \left(\alpha_j A_j k_{j0}^{\alpha_j - 1} l_{j0}^{1-\alpha_j} + Z \right) k_{j0}, \tag{15}$$

where $Z = -\delta^{\frac{1}{\zeta}} + \beta\delta^{\frac{1}{\zeta}} - \beta\frac{\zeta}{1+\zeta}\delta^{\frac{1+\zeta}{\zeta}}$ is once more a term stemming from investment transformation costs and X_j denotes the income share of capital, which can be obtained from the

[2] Since 1991, the 1986 input-output matrix has been slightly revised (Instituto Nacional de Estadistica, 1986). To facilitate a comparison with the existing literature, we use the same values as in Fernandez de Cordoba and Kehoe (2000).

aggregated input-output matrix for Spain in 1986. Equilibrium conditions also require that the returns to capital and labor are the same in both sectors, which implies that:

$$\begin{aligned} \alpha_T A_T k_{T0}^{\alpha_T - 1} l_{T0}^{1-\alpha_T} &= \alpha_N A_N k_{N0}^{\alpha_N - 1} l_{N0}^{1-\alpha_N}, \\ (1-\alpha_j) A_j k_{j0}^{\alpha_j} l_{j0}^{-\alpha_j} &= 1, \quad j = \{T, N\}, \end{aligned} \tag{16}$$

where in the last equality, we used the fact that the initial wages have been normalized to 1. Finally, we use the market clearing condition for capital:

$$k_0 = k_{T0} + k_{N0}. \tag{17}$$

The labor friction parameter, ψ, is calibrated so that job creation in the model never exceeds the highest rate of sectoral net job creation observed in Spanish data. Aggregating sectoral national accounts data on full-time equivalent jobs, we find that the largest observed net job creation rate between 1986 and 2002 was 2.5 percent in the non-traded sector (OECD, 2004b).

The left-hand column of Table 1 summarizes the initial conditions and the parameter values used when simulating the basic model.

3.2 Simulation of the basic model

When simulating the basic model, we assume that the economy is closed in 1986 and opens up to trade and capital flows in 1987.

Figure 3 presents the simulated time path for the non-traded component of the real exchange rate together with the actual data series for Spain. The model displays an initial appreciation which is too large and it cannot explain the sustained appreciation of the real exchange rate that we observe in the data. The appreciation of the real exchange rate is connected to capital inflows after the opening up to trade in the model. Since the economy can only borrow traded goods, the shock of trade liberalization makes non-traded goods relatively scarce. The investment technology specified in (8) requires the use of both traded and non-traded goods as inputs for augmenting the capital stock. In contrast to traded goods, non-traded goods must be produced at home and thus, become a bottleneck for development. The relative scarcity of the non-traded good is most acute just after liberalization, which causes its relative price to spike in the initial period.

Figures 4 and 5 present the model outcomes for the consumption of non-traded and traded goods, together with the actual data series. We see that the basic model cannot account for the observed dynamics in traded consumption. In the basic model, the consumption of traded goods immediately jumps to its new steady state level in 1987, whereas the data reveals a gradual boom in the consumption of traded goods. The basic model also under-predicts the magnitude of the consumption boom following trade liberalization.

More fundamentally, the basic model cannot account for the observed co-movement between the real exchange rate and consumption. The co-movement between the non-traded component of the real exchange rate and the consumption of non-traded goods is of the incorrect sign from 1987 and onwards in the basic model. In the basic model, the real exchange rate and non-traded consumption move in the same direction, $\Delta c_{Nt} * \Delta rer_{Nt} > 0$, for all periods after liberalization, which is in stark contrast to the data where we observe a negative co-movement, $\Delta c_{Nt} * \Delta rer_{Nt} < 0$, for Spain in many periods.

In the basic model, the consumption of non-traded goods is directly linked to the relative price of non-traded goods. As the relative price of non-traded goods, and therefore the model real exchange rate, depreciates after an initial spike in 1987, the representative consumer chooses to consume relatively more of the non-traded good over time. To successfully model the observed co-movement between the real exchange rate and consumption, mechanisms that can create a sustained appreciation of the real exchange rate and break the direct link between the relative price of non-traded goods and the consumption of non-traded goods must be introduced.

4 Augmenting the model

In this section, we investigate the qualitative effects of introducing relative productivity growth in the traded sector along the lines of Balassa-Samuelson, of gestation lags in investment, and of habit formation in preferences.

4.1 Higher productivity growth in the traded sector

As pointed out in the canonical papers by Balassa (1964) and Samuelson (1964), productivity differentials between the traded and non-traded sectors are of importance for the relative price of non-traded goods in an economy (Asea and Corden (1992) provide a good overview of the theory). Substantial empirical evidence shows countries with higher sectoral difference in total factor productivity growth to have experienced higher levels of relative inflation in the non-traded sector (De Gregorio et al. (1994)).

Differentiated productivity growth is introduced into the model by allowing for time varying total factor productivity in the production of the traded good. Since productivity in Spain has grown in both sectors since 1986, the model thus augmented can only account for effects due to differences in productivity growth between the sectors. The production functions in equations (10) and (11) are changed to

$$F_{Tt}(k_{Tt}, k_{Tt-1}, l_{Tt}, l_{Tt-1}) = A_{Tt} k_{Tt}^{\alpha_T} l_{Tt}^{1-\alpha_T} - \Phi(k_{Tt}, k_{Tt-1}) - \Psi(l_{Tt}, l_{Tt-1}) \quad (18)$$

$$F_N(k_{Nt}, k_{Nt-1}, l_{Nt}, l_{Nt-1}) = A_N k_{Nt}^{\alpha_N} l_{Nt}^{1-\alpha_N} - \Phi(k_{Nt}, k_{Nt-1}) - \Psi(l_{Nt}, l_{Nt-1}), \quad (19)$$

where we have introduced a time subscript in the traded productivity parameter, A_{Tt}. Forming a Lagrangian of the utility maximization problem in (4), we define the Lagrange multiplier on the non-traded resource constraint as p_{Nt} and the Lagrange multiplier on the traded resource constraint as p_{Tt}.

If we ignore adjustment costs, we can analytically study the effect of higher technological growth in the traded sector on the relative price of non-traded goods. Using the price of traded goods as numeraire, we follow Rebelo (1993) and study the optimality conditions for capital and labor. Equating the marginal products of capital and labor in the two sectors, we obtain

$$\alpha_T A_{Tt} k_{Tt}^{\alpha_T - 1} l_{Tt}^{1-\alpha_T} = p_{Nt} \alpha_N A_N k_{Nt}^{\alpha_N - 1} l_{Nt}^{1-\alpha_N} \tag{20}$$

$$(1-\alpha_T) A_{Tt} k_{Tt}^{\alpha_T} l_{Tt}^{-\alpha_T} = p_{Nt} (1-\alpha_N) A_N k_{Nt}^{\alpha_N} l_{Nt}^{-\alpha_N}. \tag{21}$$

Dividing equation (20) with equation (21) and rearranging, we can show the capital-labor ratio in the non-traded sector to be proportional to the capital-labor ratio in the traded sector along the equilibrium path:

$$\frac{k_{Nt}}{l_{Nt}} = \frac{\alpha_N(1-\alpha_T)}{\alpha_T(1-\alpha_N)} * \frac{k_{Tt}}{l_{Tt}}. \tag{22}$$

Plugging equation (22) into equation (21), we obtain the following expression for the relative price of non-traded goods:

$$p_{Nt} = \frac{(1-\alpha_T)}{(1-\alpha_N)} \left[\frac{\alpha_N(1-\alpha_T)}{\alpha_T(1-\alpha_N)}\right]^{-\alpha_N} * \frac{A_{Tt}}{A_N} * \left(\frac{k_{Tt}}{l_{Tt}}\right)^{\alpha_T - \alpha_N}. \tag{23}$$

In equation (23), we see that if there is no technological change in the traded sector, the relative price of non-tradables will depreciate in the long run when $\alpha_T < \alpha_N$, which is the case in our calibration for Spain. This is because the capital-labor ratio will be higher in the new steady state than in the initial period of trade liberalization, thereby making the capital intensive good relatively cheaper in the new steady state.

Faster relative technological growth in the traded sector works in the opposite direction, and tends to appreciate the relative price of non-traded goods over time, since p_{Nt} is positively dependent on the relative productivity factor, A_{Tt}/A_N. The productivity growth in the traded sector causes the real wage to rise, making the production of non-traded goods relatively more expensive. Which of the two effects that dominates is a quantitative question.

What is of importance for the non-traded component of the real exchange rate in equation (2) is the relative price of non-traded goods in Spain, relative to the same price in Germany. However, the model assumes Germany to be in steady state and the German relative price of non-traded goods to remain constant over time. The model real exchange rate is thus entirely driven by changes in the relative price of non-traded goods in Spain.

Figure 6.a compares the dynamics for the real exchange rate in the basic model and in a model where A_{Tt} grows by one percent per year during 15 years from 1986. The relative productivity growth rate was arbitrarily chosen for illustrative purposes. The parameters and initial conditions are the same, except for ψ, which is readjusted to match the maximum sectoral net job creation in the Spanish data. In line with the above discussion, we note that the real exchange rate in the basic model depreciates in the long run, whereas the model with differentiated productivity growth produces a long-run appreciation of the real exchange rate. We also see that relative productivity growth creates an even larger initial appreciation of the real exchange rate, because the economy with productivity growth starts out further away from its new steady state.

With perfect foresight, the larger wealth effect due to productivity growth after liberalization translates into increased consumption and investment demand, which leads to a higher relative price of non-traded goods than in the basic model. Figures 6.b and 6.c show the effects on consumption of non-traded and traded goods. As can be seen in Figure 6.d, the economy with productivity growth finances its higher levels of consumption by running a larger trade deficit, i.e. by borrowing more from abroad against future production. In figures 6.e and 6.f, we see that investment increases and that the economy accumulates a larger capital stock, since the return on capital increases when productivity grows.

On its own, the Balassa-Samuelson effect can only take us part of the way towards improving the dynamics for the real exchange rate in the model. Although the real exchange rate, in accordance with the data, appreciates in the long run, the initial dynamics deteriorate with higher productivity growth in the traded sector. The model with sectoral productivity differences furthermore remains unable to replicate the observed co-movement of the real exchange rate and consumption.

4.2 Time-to-build

The basic model assumes that investment goods can be transformed into capital within a year, which is a stark assumption when considering that augmenting the capital stock in the real world requires investment in infrastructure, as well as the construction of houses and factories.

Kydland and Prescott (1982) emphasized the importance of time-to-build in creating a persistent investment response to shocks in a general equilibrium model. Empirical studies have found evidence on completion times longer than two years for investment projects in many industries (Peeters (1996) and Koeva (2000)). Christiano and Todd (1996) stress that lags between investment decision and project completion also stem from the need to plan before engaging in the physical investment process.

In a two-sector economy, hit by a positive and permanent shock, Uribe (1997) points out that gestation lags combined with convex factor adjustment costs lead to a gradually increasing investment demand. A lower initial investment demand for non-traded goods could potentially improve the dynamics for the relative price of non-traded goods in our model.

With gestation lags in the model, the investment technology and the laws of motion for the capital stocks change to

$$i_{Tt} + i_{Nt} \leq G x_{Tt}^{\gamma} x_{Nt}^{1-\gamma} \tag{24}$$

$$i_{Tt} = \frac{1}{J} \sum_{i=0}^{J-1} s_{Tt-i}, \quad i_{Nt} = \frac{1}{J} \sum_{i=0}^{J-1} s_{Nt-i} \tag{25}$$

$$k_{Tt+J} = (1-\delta)\, k_{Tt+J-1} + s_{Tt} \tag{26}$$

$$k_{Nt+J} = (1-\delta)\, k_{Nt+J-1} + s_{Nt}, \tag{27}$$

where J is the number of gestation lags and s_{Tt} and s_{Nt} are the number of investment projects initiated in period t in the traded and non-traded sectors, respectively. To build s units of capital available in period $t+J$, the economy must invest s/J units of investment goods for J consecutive periods, starting in period t.

Note that the law of motion for the aggregate capital stock can be written

$$\frac{1}{J}\left[k_{Tt+J} + k_{Nt+J} + \delta \sum_{i=1}^{J-1} (k_{Tt+i} + k_{Nt+i}) - (1-\delta)\,(k_{Tt} + k_{Nt})\right] \leq G x_{Tt}^{\gamma} x_{Nt}^{1-\gamma}, \tag{28}$$

which for $J = 1$ is identical to the law of motion for capital in the basic model in equation (8).

Figure 7.a compares the dynamics for the real exchange rate in the basic model and in a model where it takes three years to build capital ($J = 3$). None of the models presented in the figure incorporate productivity growth, whereas convex investment costs are present in both models. The initial conditions and parameters are the same in the models, except for ψ, which is adjusted so that both models match the maximum sectoral net job creation in the data. We observe that the real exchange rate in the model with time-to-build appreciates much less in the initial period and then gradually appreciates for another two years, since the investment demand for non-tradable goods is reduced in the initial period and gradually increases for J periods (see figure 7.e). This leads to a gradual increase in the relative price of the non-traded good, since the supply of non-traded goods is rather inelastic up to period J (the only way of increasing non-traded output up to period J is by moving capital and labor into the non-traded sector, which is costly due to frictions in factor mobility). For higher values of J, time-to-build leads to a longer gradual appreciation of the real exchange rate.

The wealth effect associated with trade liberalization is smaller in the economy with gestation lags than in the basic model economy, since time-to-build constitutes an additional friction in capital accumulation. In figures 7.b and 7.c, this is reflected in lower steady state consumption levels. Figure 7.d shows that the reduced investment demand improves the initial trade deficit, while figure 7.f shows that the long-run capital stock is lower in the model with time-to-build.

Although the introduction of time-to-build enables us to model a gradual initial appreciation of the real exchange rate, figures 7.a-7.c reveal that gestation lags *per se* do not help explain the price-consumption regularity. Counter to what we observe in the data, the model with gestation lags still predict a positive co-movement between the real exchange rate and consumption from 1987 onwards.

To investigate the extent to which time-to-build on its own can slow down capital accumulation in the model, it is of interest to look at a model where the convex investment costs have been switched off. In Appendix B, we compare the basic model to a model where the convex costs in investment have been replaced by a time-to-build technology. The solutions show that for $J = 3$, the model economy with only time-to-build borrows more from abroad, accumulates a higher level of capital and both invests and consumes more than the basic model economy. Consequently, the initial appreciation of the real exchange rate is larger than in the basic model. To dampen the initial demand for non-traded goods in the economy with only time-to-build and labor frictions, a very high number of gestation lags would be required.

4.3 Habit formation in preferences

We now proceed to analyze the effects of introducing habit formation into the basic model.

Habit formation in preferences has the potential of making consumption in the model increase over time, although the real exchange rate is appreciating. Following Uribe (2002), we first analyze why the basic model cannot account for the observed co-movement between the real exchange rate and consumption in Spain after 1986, and then investigate the qualitative effects of introducing habit formation.

Let $u(c_t) = (c_t^\sigma - 1)/\sigma$. In the basic model, the optimality conditions for consumption of traded and non-traded goods are

$$u'(c_t)C_1\left(c_{Tt}, c_{Nt}\right) = p_{Tt} \tag{29}$$

$$u'(c_t)C_2\left(c_{Tt}, c_{Nt}\right) = p_{Nt}, \tag{30}$$

where C is the consumption aggregator defined in equation (5), and where p_{Tt} and p_{Nt} are the Lagrange multipliers on the resource constraints for the traded and non-traded sectors, respectively. Dividing equation (30) with equation (29), and using the price of traded goods as numeraire, we obtain an expression for the relative price of non-traded goods,

$$p_{Nt} = \frac{(1-\varepsilon)}{\varepsilon}\left(\frac{c_{Tt}}{c_{Nt}}\right)^{1-\rho}, \tag{31}$$

which for negative values of ρ tells us that the relative price of non-traded goods is increasing in the ratio c_{Tt}/c_{Nt}. The optimality condition for foreign bonds, b_{t+1}, is given by

$$p_{Tt} = \beta(1+r)p_{Tt+1}, \tag{32}$$

which, since the world gross interest rate is equal to the inverse of the discount rate in our small open economy, implies that the marginal utility of consuming traded goods should be constant over time. Equation (32) thus explains why consumption of traded goods immediately jumps to its steady state level in the basic model. With consumption of traded goods being constant, equation (31) forces the consumption of non-traded goods to vary negatively with the relative price of non-traded goods, and hence to vary positively with the non-traded component of the real exchange rate. As pointed out in the previous sections, this is at odds with the price-consumption regularity in the data.

When habit formation is introduced in the model, the discounted sum of utility in (4) changes to

$$\sum_{t=0}^{\infty}\beta^t\left[\frac{(c_t-\theta c_{t-1})^{\sigma}-1)}{\sigma}\right], \tag{33}$$

where $\theta \in [0,1)$ is a habit stock parameter. The optimality condition for the consumption of traded goods in equation (29) becomes

$$\left[u'(c_t-\theta c_{t-1}) - \ \theta\beta u'(c_{t+1}-\theta c_t)\right] C_1\left(c_{Tt}, c_{Nt}\right) = p_{Tt}, \tag{34}$$

which together with equation (32) implies that the consumption of traded goods can vary over time in the model. Equation (31) still holds in the model with habit formation, but with the consumption of traded goods varying, the model no longer forces the consumption of non-traded goods and the relative price of non-traded goods to move in different directions. In the model, an increasing relative price of non-traded goods is compatible with an increase in the consumption of non-traded goods, as long as the consumption of traded goods increases more. Interestingly, a look at the data in figures 1 and 2 reveals that this is exactly what happened in Spain after 1986.

Habit formation introduces an addictive element in preferences. The more one eats, the hungrier one wakes up in the next period. The wealth effect associated with trade liberalization therefore results in a gradual increase in the consumption of both goods. This is illustrated in figures 8.b and 8.c, where we compare the consumption dynamics in the basic model and in a model with habit formation. Neither of the models incorporate productivity growth or gestation lags in investment. For the model with habit formation, we have chosen a value of $\theta = 0.8$.

In figure 8.a, we see that the initial reduction and the gradual increase in consumption demand due to habit formation on its own is not sufficient to create a sustained appreciation of the real exchange rate in our model. Non-traded goods are still most scarce in the initial period, and the reduced consumption demand can only dampen the initial spike in the relative price of non-traded goods.

Figures 8.d to 8.f show that the trade deficit improves in the model with habits, whereas initial investment increases to build a larger capital stock that can sustain higher long-run levels of consumption.

The effects of introducing habit formation in the basic model stand in contrast to the model developed by Uribe (2002), where habit formation leads to a gradual appreciation in the real exchange rate. In that model, there is no capital accumulation in the non-traded sector, which makes the supply of non-traded goods more inelastic than in the model presented here. Furthermore, non-traded goods are not used as inputs into investment, which eliminates the effects of investment demand that play an important role in determining the relative price of non-traded goods in our model. A gradually increasing consumption demand can therefore create a gradual appreciation of the real exchange rate in the model presented by Uribe (2002).

5 Calibration of the augmented model

To evaluate the quantitative significance of the three mechanisms discussed in the previous section, we calibrate a model incorporating higher technological growth in the traded sector, gestation lags in investment, and habit formation in preferences. For the parameters governing time-to-build and habit formation, we use standard values in the literature, while productivity differentials are measured in sectoral growth accounting for Spain and Germany.

5.1 Calibration of time-to-build and habit formation

Kydland and Prescott (1982) note the average construction time for plants to be around two years. Peeters (1996) finds that the completion of investment projects often takes more than two years and Koeva (2000) provides evidence of the average time from decision to completion of a plant being more than two years in industries such as food, textile communications, wholesale, transportation and utilities. According to the input-output matrices published by Instituto Nacional de Estadistica (1986-1994, 1995-1998), construction was the most important investment input in Spain between 1986 and 1998. In calibrating the model, we therefore choose a value of $J = 3$, implying that it takes three years to put new capital in place after trade liberalization.

Following Uribe (1997) and Koeva (2001), the augmented model incorporates both convex adjustment costs in investment and time-to-build. As discussed in Appendix B, a model with only time-to-build displays oscillatory solutions and cannot improve the initial dynamics for the relative price of non-traded goods.[3]

Although microeconometric evidence on habit formation is scarce, empirical work using aggregate data has found support for the inclusion of previous consumption levels in the utility function (Constantinides and Ferson (1991) and Fuhrer (2000)). In the macroeconomic literature, Constantinides (1990) used a value of $\theta = 0.8$ to explain the equity premium puzzle, while Jermann (1998) and Boldrin et al. (2001) find that values of θ between 0.73 and 0.82 best enable real business cycle models to replicate the properties of the business cycle and asset prices in the US economy. Therefore, we will use a value of $\theta = 0.8$ in the simulation of our augmented model.

5.2 Measurement of sectoral productivity growth

Our modelling framework assumes Germany to be in steady state and there to be no differences in productivity growth between the traded and non-traded sectors in Germany. To augment the model in a realistic fashion, the observed growth in relative sectoral productivity for Spain should therefore be adjusted for the growth in relative sectoral productivity observed in Germany.

To measure the growth of sectoral productivity in both countries, we first estimate capital stocks consistent with a three period time-to-build technology. Then, we use data on aggregate capital, sectoral output and sectoral labor inputs to compute the sectoral productivities and capital stocks implied by the equilibrium conditions of the model. The data sources and the details of the method used in our sectoral growth accounting exercise are given in Appendix A.

By relative sectoral productivity in period t, we mean A_{Tt}/A_{Nt}. Since the model assumes productivity in the non-traded sector to be constant over time, the growth of relative sectoral productivity in the model is given by the productivity growth in the traded sector. The annual growth rate for traded sector productivity in the model should be set to capture the observed difference between the growth rates in relative sectoral productivity for Spain and Germany,

$$\frac{A_{Tt} - A_{Tt-1}}{A_{Tt-1}} = \frac{\left(A^S_{Tt}/A^S_{Nt}\right)}{\left(A^S_{Tt-1}/A^S_{Nt-1}\right)} - \frac{\left(A^G_{Tt}/A^G_{Nt}\right)}{\left(A^G_{Tt-1}/A^G_{Nt-1}\right)}, \tag{35}$$

where superscripts S and G denote the observed productivities for Spain and Germany, respectively.

[3] One problem with including both types of capital frictions is that the estimation of ζ in Eberly (1997) is based on a model without gestation lags. However, as we will discuss later, the outcomes of the augmented model are not sensitive to the precise value of the investment cost parameter.

Due to the quality of the data and the particular form of the equilibrium conditions used in our exercise, we should not put too much emphasis on any one observation of the measure in equation (35). According to our calculations, the average annual growth rate of relative sectoral productivity between 1986 and 2001 was 4.72 percent in Spain and 3.28 percent in Germany. Therefore, we feed a yearly growth rate of 1.44 percent for productivity in the traded sector between 1986 and 2001 into the augmented model. From 2001, we assume that the difference between Spain and Germany decreases linearly, to completely have vanished by 2010.

Our results on relative productivity are in line with the Balassa-Samuelson framework. As noted in figure 1, Spain has had a higher inflation in the non-traded sector than Germany over the 1986-2001 period and, according to our calculations, it also has had a higher growth in relative sectoral productivity. Furthermore, the measured productivity differential is in line with empirical work by Sinn and Reutter (2001) who find that the relative sectoral labor productivity grew faster in Spain than in Germany after 1986. They estimate the average difference in sectoral relative labor productivity between Spain and Germany to be 1.94 percentage points between 1987 and 1995.[4]

The sectoral growth accounting is robust to the capital stock estimates that we employ. Using the capital stock estimates of Conesa and Kehoe (2003) for Spain and the sectoral capital stocks in the OECD STAN database (OECD, 2004) for Germany, we arrive at an average relative productivity growth differential of 1.51 percentage points over the 1992-2000 period.

The initial conditions and parameter values used in the simulation of the augmented model are presented in the right-hand column of Table 1.

6 Simulation of the augmented model

Figure 9 compares the Spanish data with the dynamics for the real exchange rate and consumption in the basic model and the augmented model. In figures 9.a and 9.b, we see that the augmented model can explain a much larger part of the observed fluctuations in the real exchange rate than the basic model. In the augmented model, time-to-build and habit formation dampen the initial appreciation of the real exchange rate. The three-period time-to-build technology leads the real exchange rate to gradually appreciate during the three initial periods, while relative sectoral productivity growth causes the model real exchange rate to appreciate in the long run.

Figures 9.c to 9.f further reveal that the augmented model can also account for a larger part of the observed co-movement between the real exchange rate and consumption than

[4] Sinn and Reutter (2001) define labor productivity as value added, divided by employment. Replicating their study with our data on real value added and employment, we arrive at an average relative labor productivity differential of 1.61 percentage points per year.

the basic model. The augmented model does not fully account for the observed co-movement, but in several periods the model real exchange rate is appreciating while the consumption of both traded and non-traded goods increases. Habit formation causes the consumption of both traded and non-traded goods to increase over time, although the relative price of non-traded goods is appreciating. We also see that habit formation and the wealth effect of productivity growth lead to consumption booms closer to what we observe in the data than in the basic model.

To evaluate the augmented model, it is important to investigate how it performs for other real variables as compared to the basic model. In figure 10, we compare the two models with Spanish data for the trade balance, the relative size of the traded sector, real GDP, the relative size of the labor force in the traded sector and aggregate investment. The figure reveals that the augmented model matches the data better or equally well in all dimensions, except the trade balance. Higher productivity growth in the traded sector causes the augmented model economy to borrow more against future income in the early stages of transition. The first and second columns of table 2 present the mean square errors for the basic model and the augmented model for all variables examined in figures 9 and 10. The data sources and the methods used in producing the figures are given in Appendix A.

6.1 Sensitivity analysis

The dynamics of the augmented model are robust to varying the parameter governing the elasticity of substitution across goods, ρ, and the parameter governing the intertemporal elasticity of substitution, σ. For values of ρ and σ between -0.5 and -4, the model outcomes for the real exchange rate and its co-movement with consumption only change slightly.

The exact value of the habit stock parameter, θ, does not matter for the ability of the augmented model to better replicate the observed price-consumption dynamics. For a value of $\theta = 0.5$, the model predicts a slightly larger initial appreciation of the real exchange rate and a slightly larger trade deficit, while the consumption of both traded and non-traded goods increases over time. For values of θ above 0.8, the model displays a smaller initial appreciation of the real exchange rate, a smaller trade deficit and a larger consumption boom.

The outcomes of the augmented model are not sensitive to the precise value of the investment cost parameter, ζ, partly because the labor friction parameter, ψ, is calibrated so that each version of the model matches the maximum sectoral job creation rate in the data. A higher value of ζ thus implies a lower value of ψ, and vice versa.

The quantitative results of the augmented model are sensitive to the growth rate of productivity in the traded sector which we use in the model. For a higher annual growth rate than 1.44 percent between 1986 and 2001, the model displays a larger initial appreciation of the real exchange rate and a larger trade deficit. The reason, as discussed in section 4.1, is that the model economy starts out further from its new steady state which, in our environment of perfect foresight, leads to more borrowing against future income to optimally smooth consumption. Similarly, changing our assumption that the relative sectoral productivity differential between Spain and Germany will vanish by 2010 would also affect the dynamics of the model. If the productivity difference were to vanish earlier, the fluctuations in the trade deficit and the initial appreciation of the real exchange rate would be dampened in the model.

The number of gestation lags in the time-to-build technology affects the ability of the augmented model to account for the price-consumption regularity in the initial periods after trade liberalization. In figures 11 and 12, we compare the Spanish data with the dynamics in the basic model and an augmented model with $J = 2$, whereas figures 13 and 14 present the corresponding comparison for a model where $J = 5$. The figures reveal that for any number of gestation lags between $J = 2$ and $J = 5$, the augmented model performs better than the basic model in the price-consumption dimension, while performing worse only for the trade deficit. Although a construction period of five years may be unrealistically long, it is intriguing to see how well the model with $J = 5$ can account for the observed fluctuations in the real exchange rate, consumption and investment. The mean square errors for the two models are reported in the third and fourth columns of table 2.

7 Concluding remarks

The analysis has shown that introducing higher productivity growth in the traded sector, time-to-build and habit formation enhances the quantitative performance of the standard two-sector model we use to simulate the Spanish economy after the accession to the European Community. A calibrated version of the augmented model can better account for the price-consumption dynamics after trade liberalization, than the model developed by Fernandez de Cordoba and Kehoe (2000). The magnitudes of the fluctuations in the real exchange rate and consumption improve considerably in the augmented model. Although it cannot fully account for the observed co-movement of the real exchange rate and consumption in Spain, the augmented model displays dynamics where the real exchange rate appreciates in several periods, while the consumption of both traded and non-traded goods increases.

In enhancing the model's capacity to replicate the observed price-consumption dynamics in Spain, the investigated mechanisms have different effects. By decreasing the initial demand for non-traded goods, time-to-build and habit formation dampen the initial appreciation of the real exchange rate in the augmented model. The time-to-build technology also causes investment demand to gradually increase in the model, which leads to a gradual appreciation of the real exchange rate in the initial periods after trade liberalization, while higher productivity growth in the traded sector causes the model real exchange rate to appreciate in the long run. Habit formation in preferences makes the consumption of both traded and non-traded goods increase over time, although the relative price of non-traded goods is appreciating.

The analysis further showed that the augmented model does not lose explanatory power for other real variables compared to the benchmark model, with the exception of the trade balance, which deteriorates due to productivity growth. We therefore conclude that the mechanisms investigated in the paper constitute extensions of the two-sector framework that are important for the quantitative analysis of small open economies in transition.

A Data

To construct the real exchange rate series labeled rer in figure 1, we use the peseta/DM nominal exchange rate and the Consumer Price Index for each country. When constructing price indices for traded goods (P_{Tt}^{S} and P_{Tt}^{G}) to calculate rer_N in figure 1, we use Producer Price Indices for the manufacturing sector in Germany and Industrial Prices for Spain. The real exchange rate data is taken from the IFS database (IMF, 2004).

The sectoral consumption series in figure 2 are obtained by aggregating input-output tables for Spain 1986-1994, and tables of total use for the years 1995-1998. The input-output tables were purchased from the Instituto Nacional de Estadistica (1986-1994), while the tables for 1995-1998 were obtained from the web site of the Instituto Nacional de Estadistica. The sectoral consumption figures are deflated using industrial prices for traded goods and the sectoral value added deflator for non-traded goods. The sectoral value added deflator is obtained from the SourceOECD database (OECD, 2004a).

In line with Peeters (1996), the aggregate capital stock estimates in section 5.2 are calculated by adjusting the Perpetual Inventory Method to accommodate three gestation lags according to equation (28). We use a value of $\delta = 0.056$ for both Germany and Spain and data on Gross Fixed Capital Formation from the IFS (IMF, 2004). The capital-output ratios for 1965-1967 in the Penn World Table were used to obtain the starting values for the capital stocks (Summers et al. (1995)). Using data on nominal GDP from the IFS database (IMF, 2004), we calculate aggregate capital-output ratios for both Germany and Spain, which together with data on real GDP in the sourceOECD database (OECD, 2004a) enable us to calculate the aggregate capital stocks used in equation (38).

For each country, the sectoral productivity parameters and capital stocks are found by solving the following system of equations for $t = (1986, 1987, ..., 2001)$,

$$\begin{aligned} y_{Tt} &= A_{Tt} k_{Tt}^{\alpha_T} l_{Tt}^{1-\alpha_T} - \Phi(k_{Tt}, k_{Tt-1}) && (36) \\ y_{Nt} &= A_{Nt} k_{Nt}^{\alpha_N} l_{Nt}^{1-\alpha_N} - \Phi(k_{Nt}, k_{Nt-1}) && (37) \\ k_t &= k_{Tt} + k_{Nt} && (38) \\ (1-\alpha_T) A_{Tt} k_{Tt}^{\alpha_T} l_{Tt}^{-\alpha_T} &= p_{Nt}(1-\alpha_N) A_{Nt} k_{Nt}^{\alpha_N} l_{Nt}^{-\alpha_N}, && (39) \end{aligned}$$

where the unknowns are A_{Tt}, A_{Nt}, k_{Tt} and k_{Nt} and where we have ignored labor frictions. For 1986, the system is assumed to be in steady state, so that the sectoral capital stocks in 1985 were the same as in 1986. For the convex capital adjustment cost, we use a value of $\zeta = 1.29$ for Germany as estimated by Eberly (1997). The capital intensity parameters α_T and α_N are both assumed to equal 0.3 in Germany, which is a fair approximation according to Gollin (2002).[5] The data on sectoral GDP and labor shares used in equations (36), (37)

[5] We could improve on this approximation using a German input-output table to obtain values for α_T and α_N. The calculated relative sectoral productivities are not very sensitive to the sectoral capital

and (39) are also obtained from the sourceOECD database (OECD, 2004a, 2004b). For Germany, the labor data was complemented for the period 1986-1990 with data from the micro census of Statistisches Bundesamt (2003). The German unification in 1991 causes a jump in the data series which we use for output and investment, but the resulting jump in our productivity measures for Germany are symmetric across the two sectors.

One possible estimate of the relative price of non-traded goods, p_{Nt}, in equation (39) would be the ratio of the non-traded value added deflator and the producer price index. To numerically solve the system of equations in (36)-(39), we use a model-based estimate of p_{N_t} that ignores factor frictions, however.[6] Both the estimate directly available in the data and our model-based estimate appreciate by about 31 percent more in Spain than in Germany during the period 1986 to 2001, which indicates that the effects of ignoring factor frictions are close to symmetric across the two countries.

When solving the system in equations (36) to (39), we ignore labor frictions, since the value of ψ used in the model will depend on the calculated productivity growth (remember that ψ is calibrated so that the model replicates the maximum sectoral job creation rate in the data). The inconsistency resulting from ignoring labor frictions in the sectoral growth accounting for both countries is only likely to have a small effect, however.[7] According to equation (13), labor movement between sectors would have a similar effect on the measured productivity parameters in both sectors for $\psi > 0$, which means that the relative productivity measure would be close to that obtained when ignoring labor frictions. The share of the labor force working in the traded sector has furthermore decreased in both Spain and Germany over the 1986-2001 period, so that part of the errors resulting from ignoring labor frictions can be expected to cancel out in equation (35).

It would be desirable to investigate whether it is possible to develop an algorithm that makes use of the relative price estimate available in the data, that accounts for both labor and capital frictions, and that iteratively calculates sectoral productivities to find a value of ψ consistent with both the model and the data.

In figure 10, the trade balance as a percentage of GDP is calculated using data from IFS (IMF, 2004) on the trade balance and GDP. To construct the series for traded output as a percentage of GDP, for real GDP and for the labor share in the traded sector, we use data from the SourceOECD database (OECD, 2004a, 2004b). The data on investment was

intensities, however.

[6] Ignoring factor frictions, the relative price of non-traded goods can be expressed as

$$p_{Nt} = \frac{(1-\alpha_T) y_{Tt} l_{Nt}}{(1-\alpha_N) y_{Nt} l_{Tt}}.$$

[7] A value of $\psi = 2.29$, as in the basic model, implies that, for both countries, the average cost of labor frictions according to the data would be smaller than 1 percent of output in both the traded and the non-traded sectors.

obtained by deflating and adding the sectoral investment series in the aggregated input-output tables and the tables of total use provided by Instituto Nacional de Estadistica (1986-1994, 1995-1998).

B The effects of substituting convex investment costs with time-to-build

Time-to-build constitutes a friction in investment that slows down capital accumulation in the model. To investigate what effects time-to-build has on its own, it is of interest to look at a model with gestation lags where the convex investment costs have been switched off.

Figure 15 compares the dynamics in the basic model and a model where the convex adjustment costs in investment have been replaced by a three period time-to-build technology ($J = 3$). In both models, the labor friction parameter, ψ, has been adjusted so that the models match the maximum sectoral job creation rate in the data. The first thing to note is the saw-tooth pattern of the dynamics in the model with time-to-build. As explained by Rouwenhorst (1991) and Christiano and Todd (1996), the oscillatory solutions are due to the'Leontief type' technology for producing capital and stem from an effort to concentrate investment activities and consumption in periods of relative abundance.

The solutions show that for $J = 3$, the model economy with only time-to-build borrows more from abroad, accumulates a higher level of capital and both invests and consumes more than the basic model economy. The reason is that a three-period time-to-build technology constitutes a smaller capital friction than the convex investment costs as estimated by Eberly (1997), which implies that the wealth effect from trade liberalization is larger in the model with time-to-build. In figure 15.a, we consequently see that the real exchange rate in the model with only time-to-build initially appreciates more than in the basic model, since non-traded goods are more scarce in the first period after liberalization.

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Table 1: Calibration of the basic and the augmented models

	Basic model	**Augmented Model**
Initial conditions		
y_0	100.00	100.00
y_{T0}	37.1458	37.1458
y_{N0}	62.8542	62.8542
k_0	207.1086	207.1086
k_{T0}	73.0841	73.0841
k_{N0}	134.0245	134.0245
L	67.9729	67.9729
l_{T0}	25.8416	25.8416
l_{N0}	42.1313	42.1313
Parameters		
A_{T0}	1.0511	1.0511
A_N	1.0217	1.0217
α_T	0.3125	0.3125
α_N	0.3383	0.3383
γ	0.3802	0.3802
G	1.9434	1.9434
σ	-1	-1
ρ	-1	-1
ε	0.2537	0.2537
δ	0.0576	0.0576
β	0.9463	0.9463
ζ	1.6133	1.6133
ψ	2.2974	6.4014
J		3
θ		0.8

Table 2: Mean square errors for the models presented in figures 9 to 14

Variable	**Basic**	**Augmented, J=3**	**J=2**	**J=5**
rer_N	0.0089	0.0016	0.0024	0.0005
c_N	0.0087	0.0025	0.0024	0.0026
c_T	0.0336	0.0054	0.0050	0.0058
trade balance	6.3197	28.5834	27.2015	31.2914
traded output	66.9278	31.5161	32.9827	29.1583
real GDP	0.0934	0.0598	0.0547	0.0695
traded sector labor share	0.0072	0.0033	0.0035	0.0029
investment	0.0852	0.1099	0.1885	0.0222

Figure 1. Bilateral Spanish-German real exchange rates

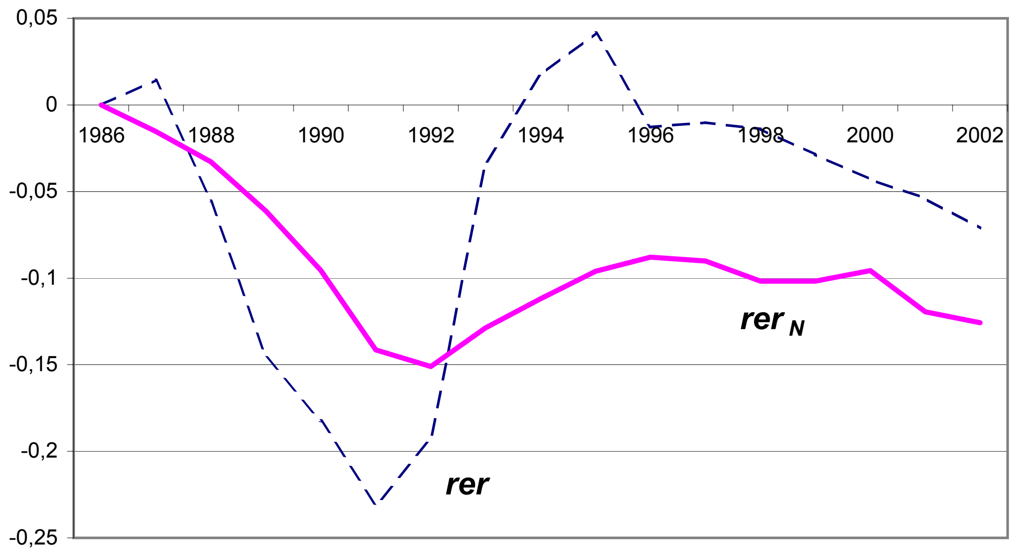
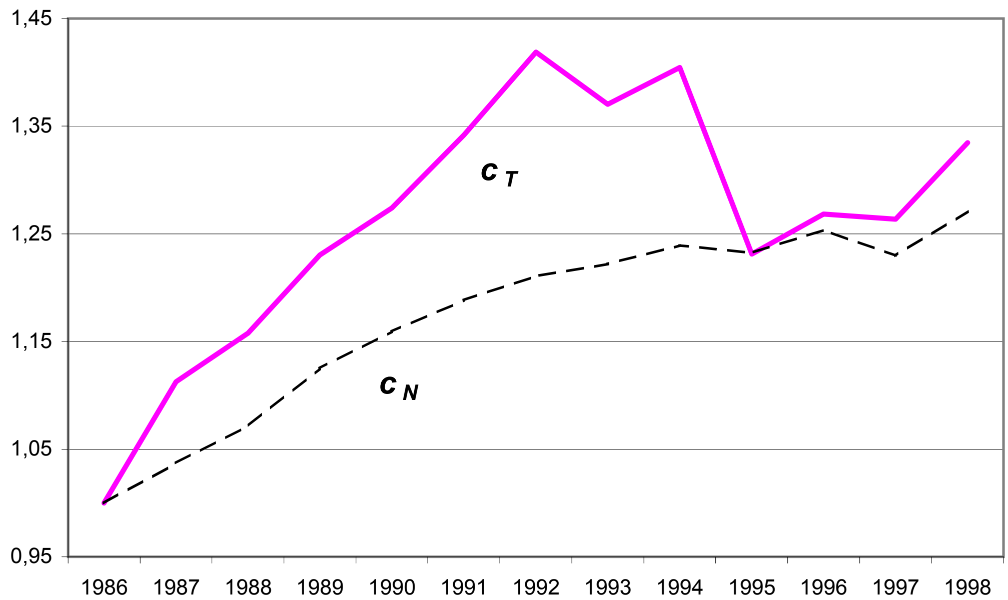


Figure 2. Consumption of traded and non-traded goods in Spain



The Price-Consumption Dynamics in the Basic Model

Figure 3. rer_N

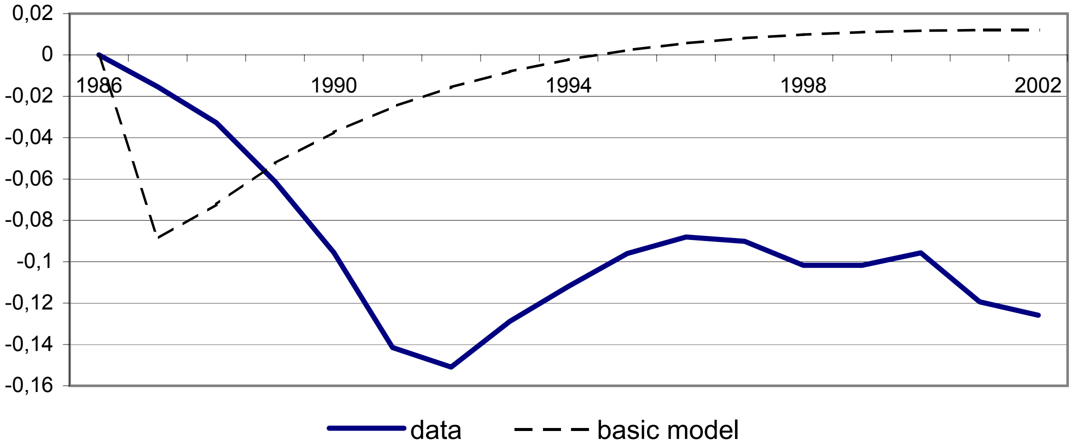


Figure 4. c_N

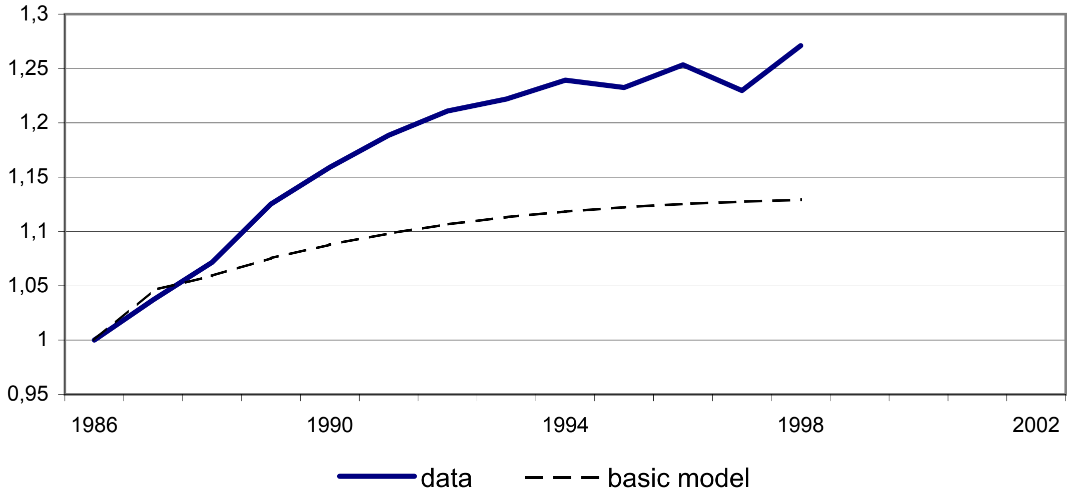


Figure 5. c_T

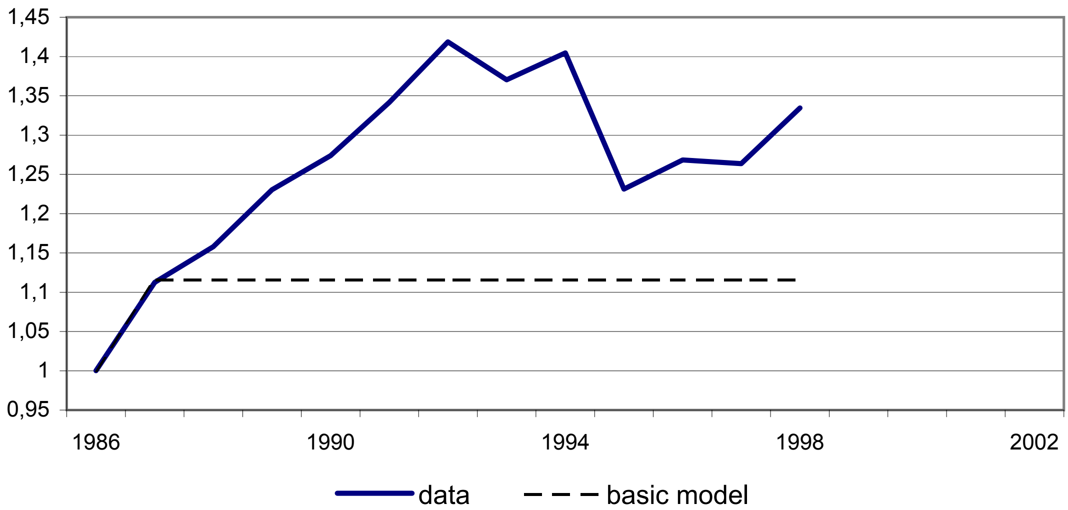


Figure 6. The effects of higher productivity growth in the traded sector

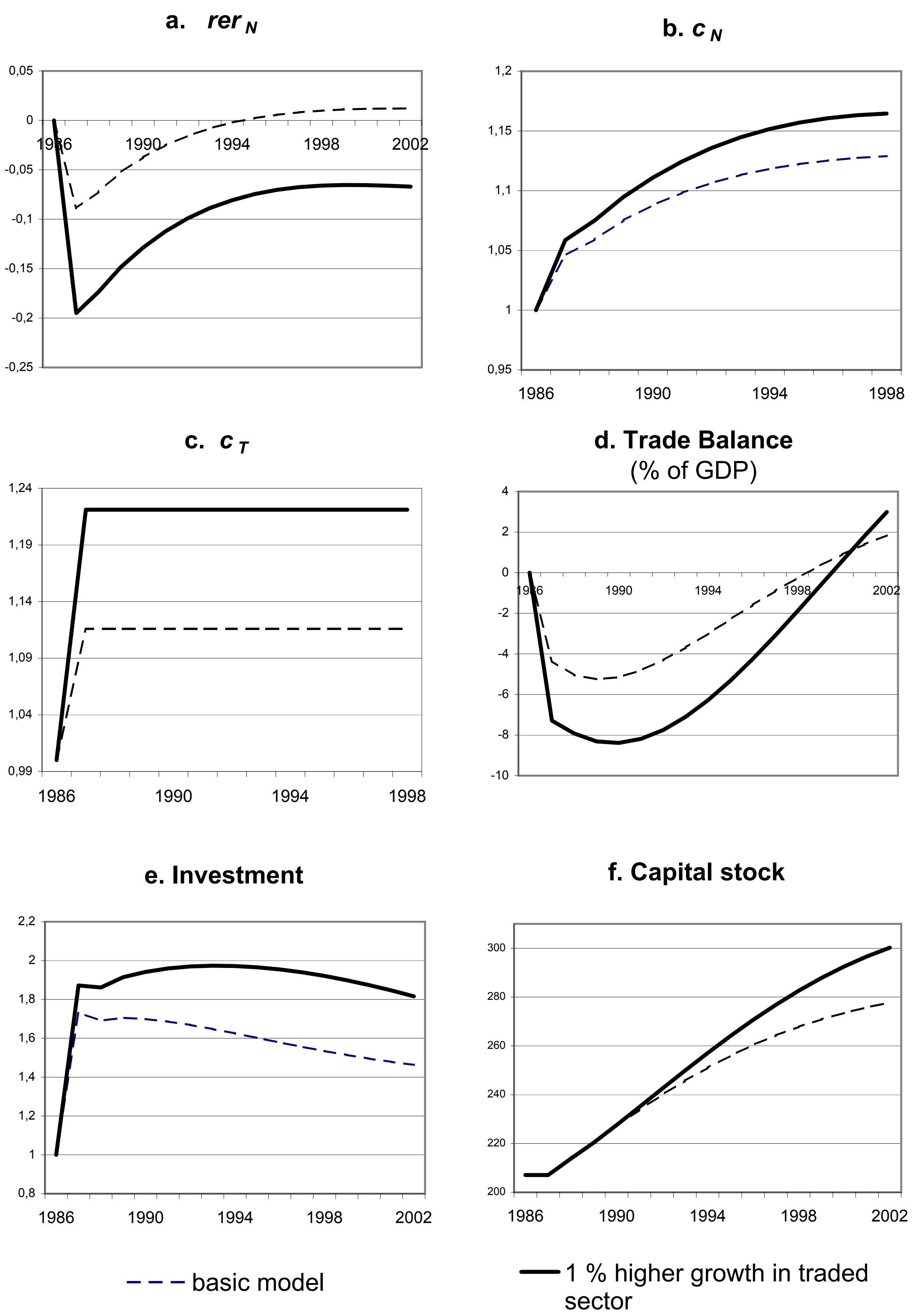


Figure 7. The effects of time-to-build

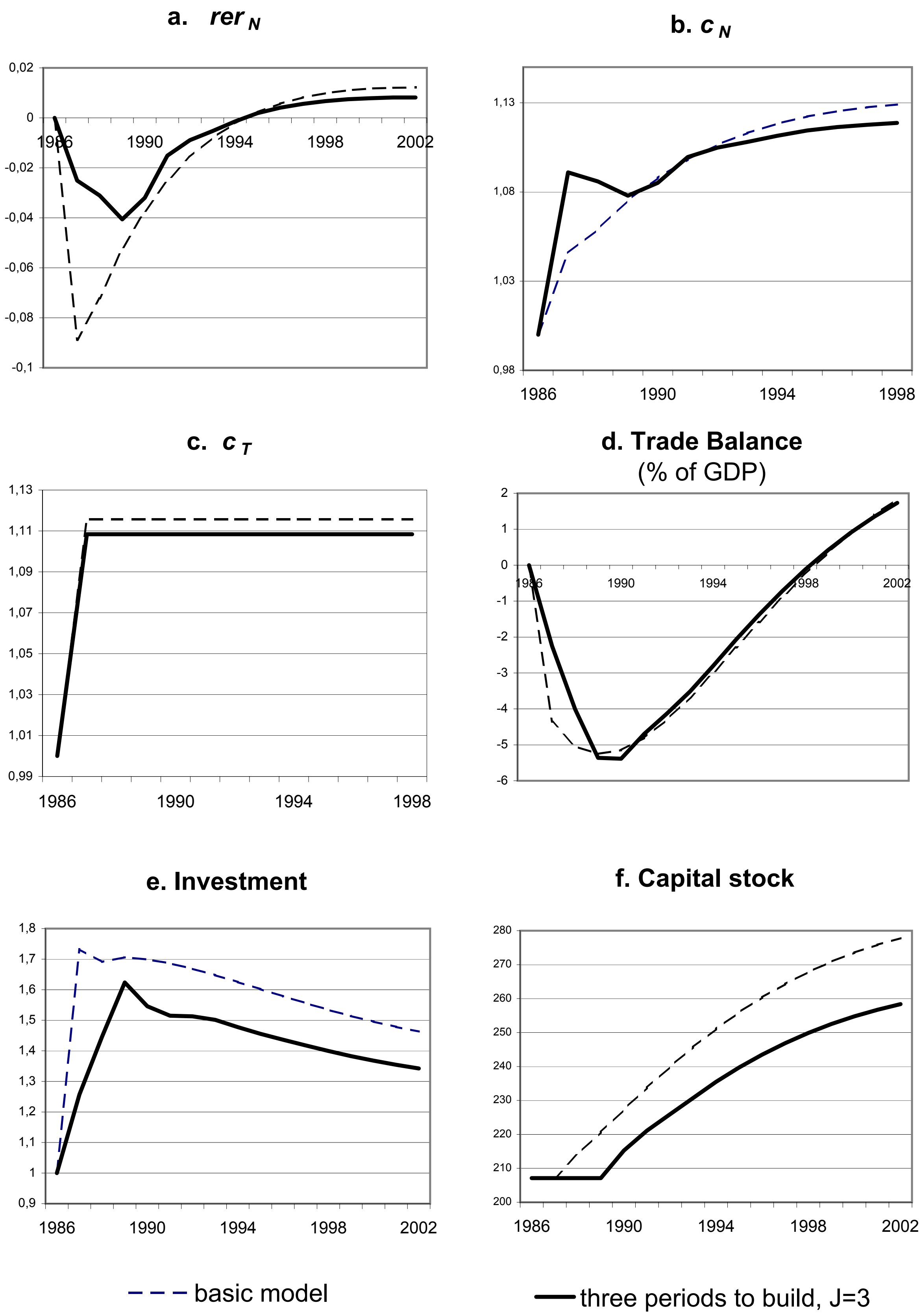


Figure 8. The effects of habit formation in preferences

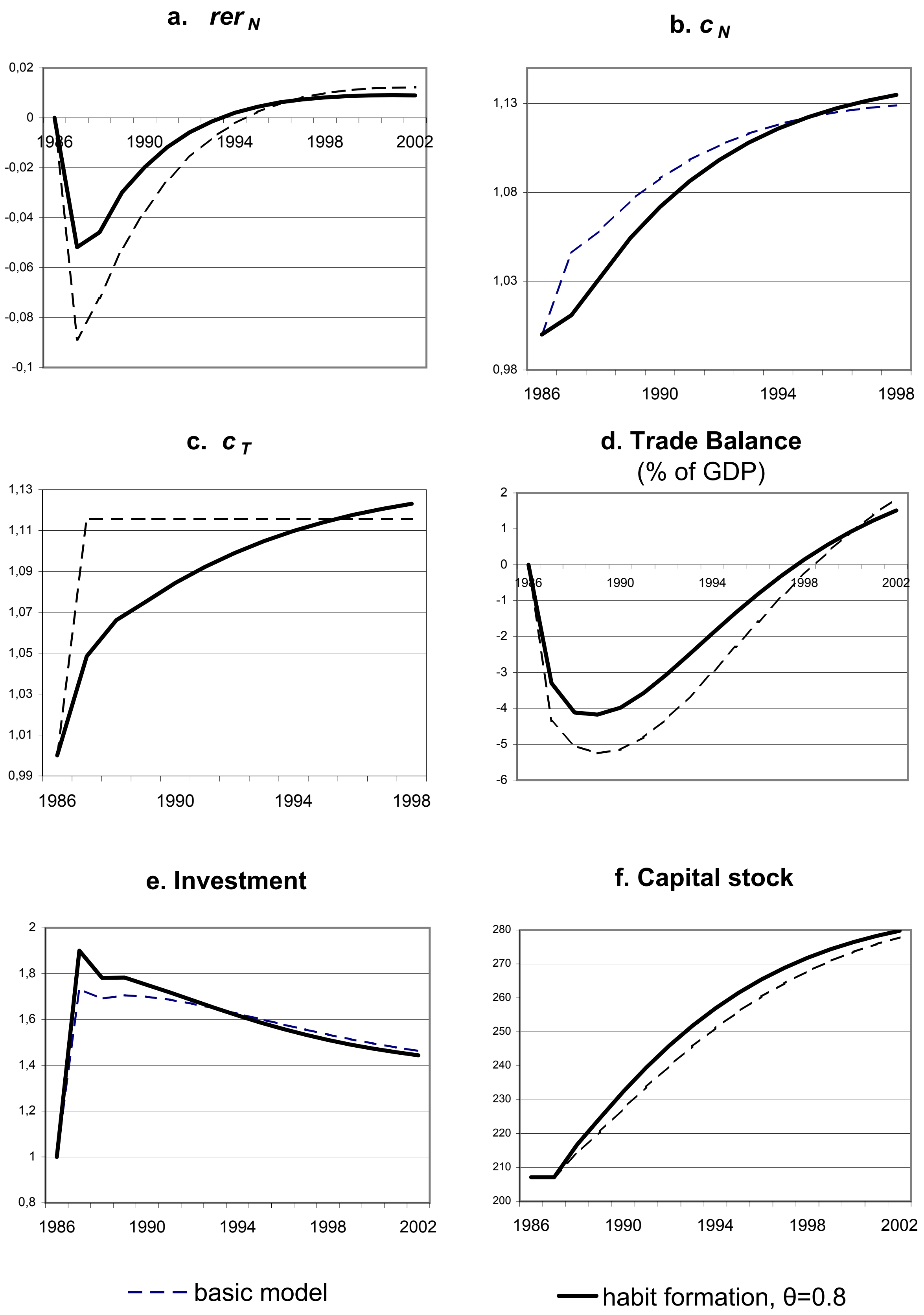


Figure 9. Comparison in the Price-Consumption dimension

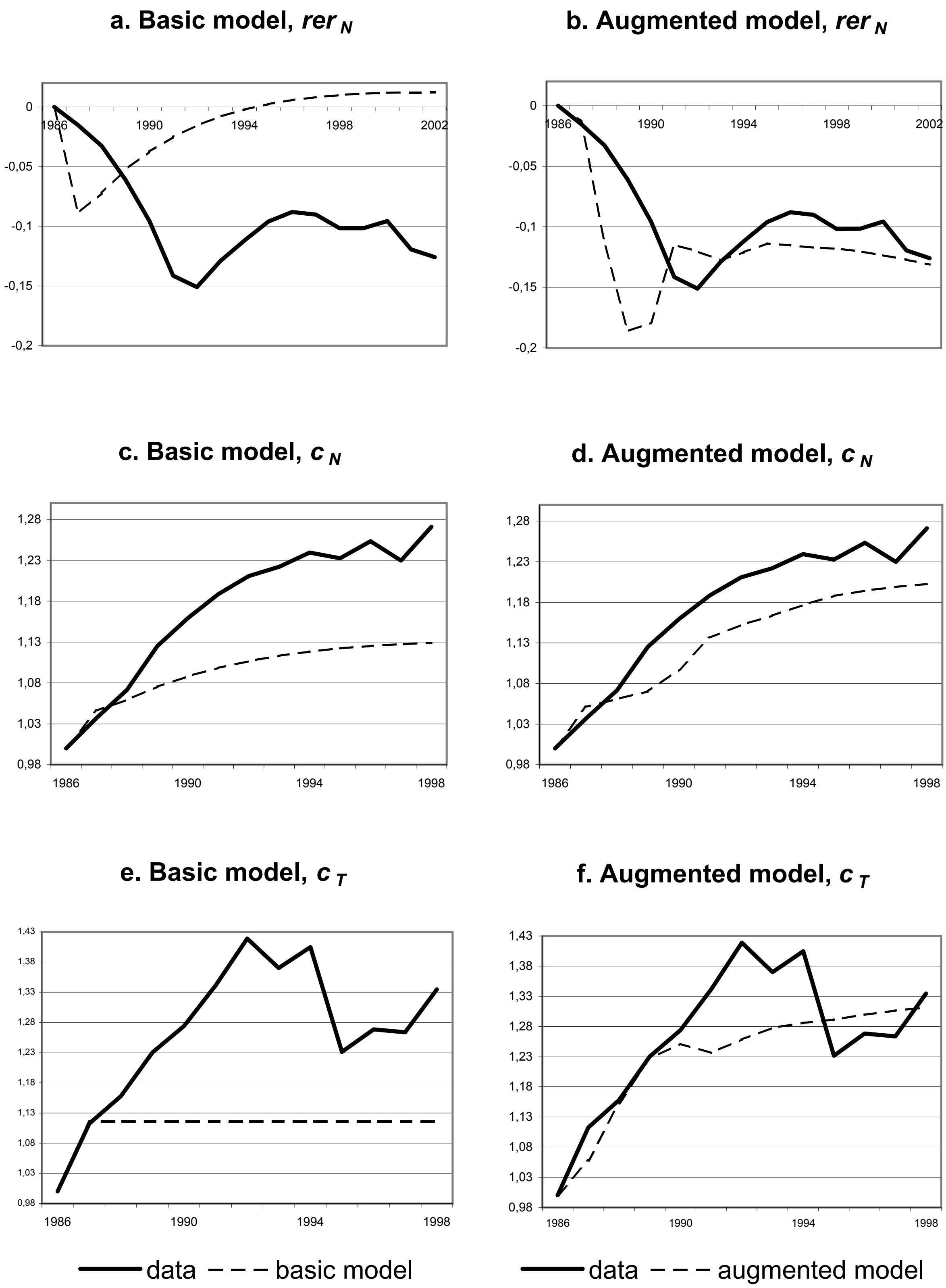


Figure 10. Comparison for other real variables

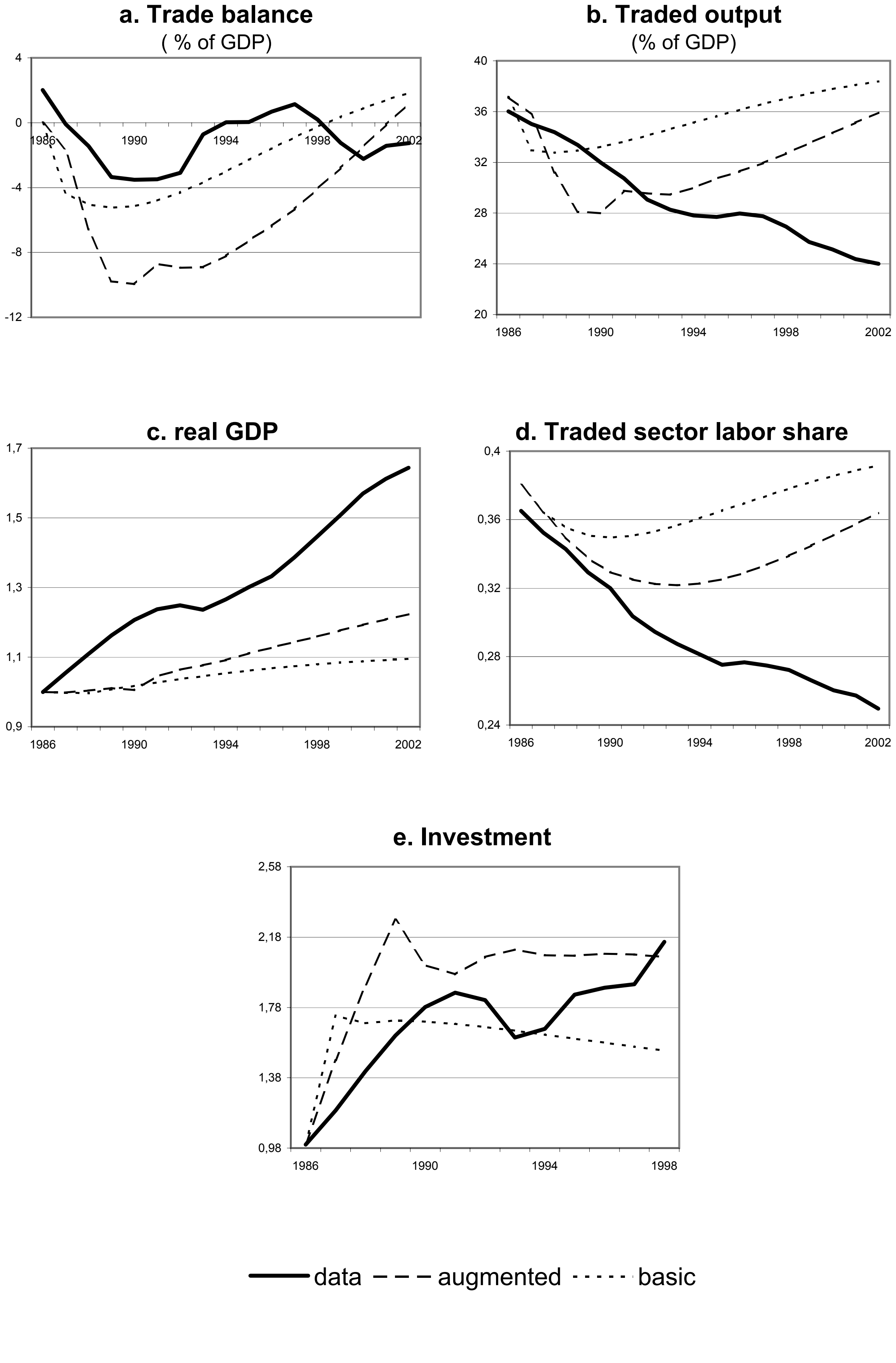
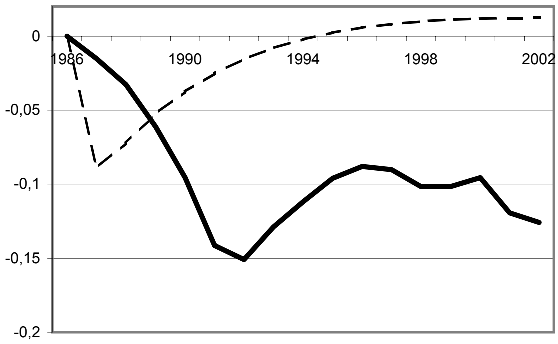
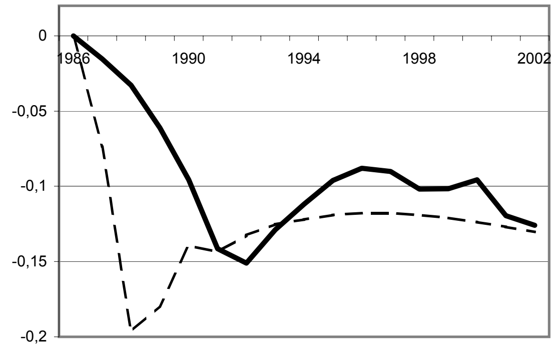


Figure 11. Comparison in the Price-Consumption dimension
(J=2 in augmented model)

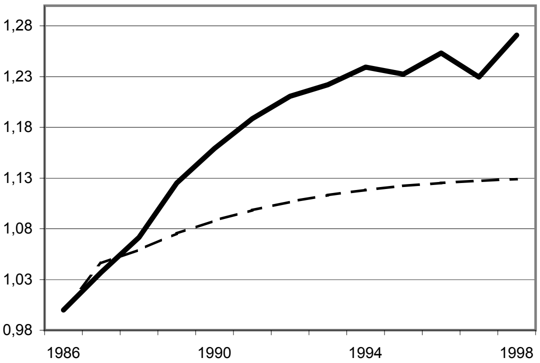
a. Basic model, *rer*$_N$



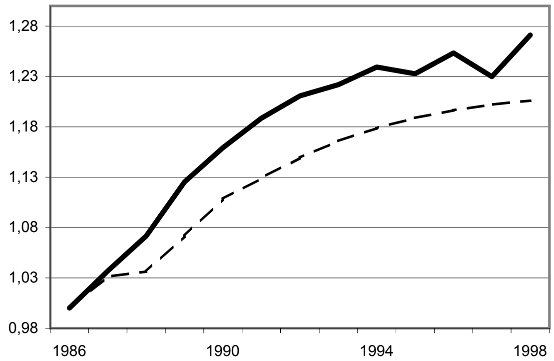
b. Augmented model, *rer*$_N$



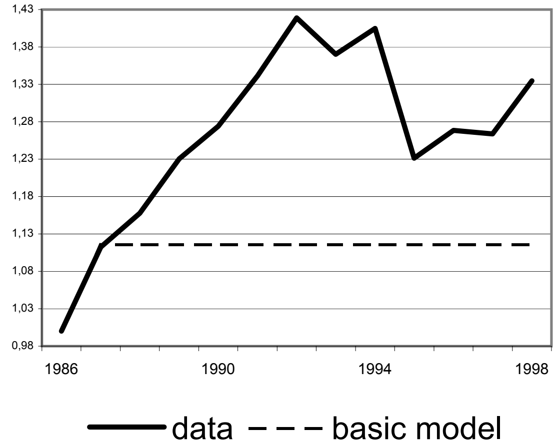
c. Basic model, *c*$_N$



d. Augmented model, *c*$_N$



e. Basic model, *c*$_T$



f. Augmented model, *c*$_T$

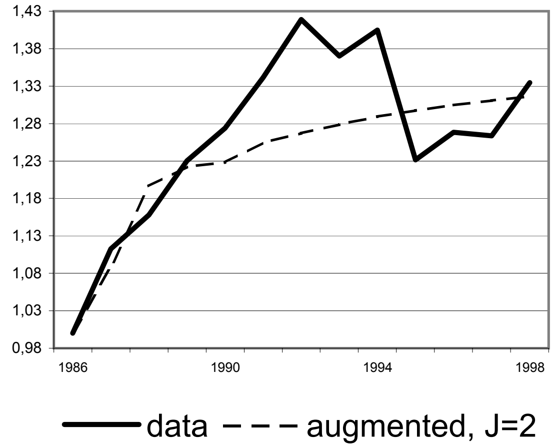


Figure 12. Comparison for other real variables
(J=2 in augmented model)

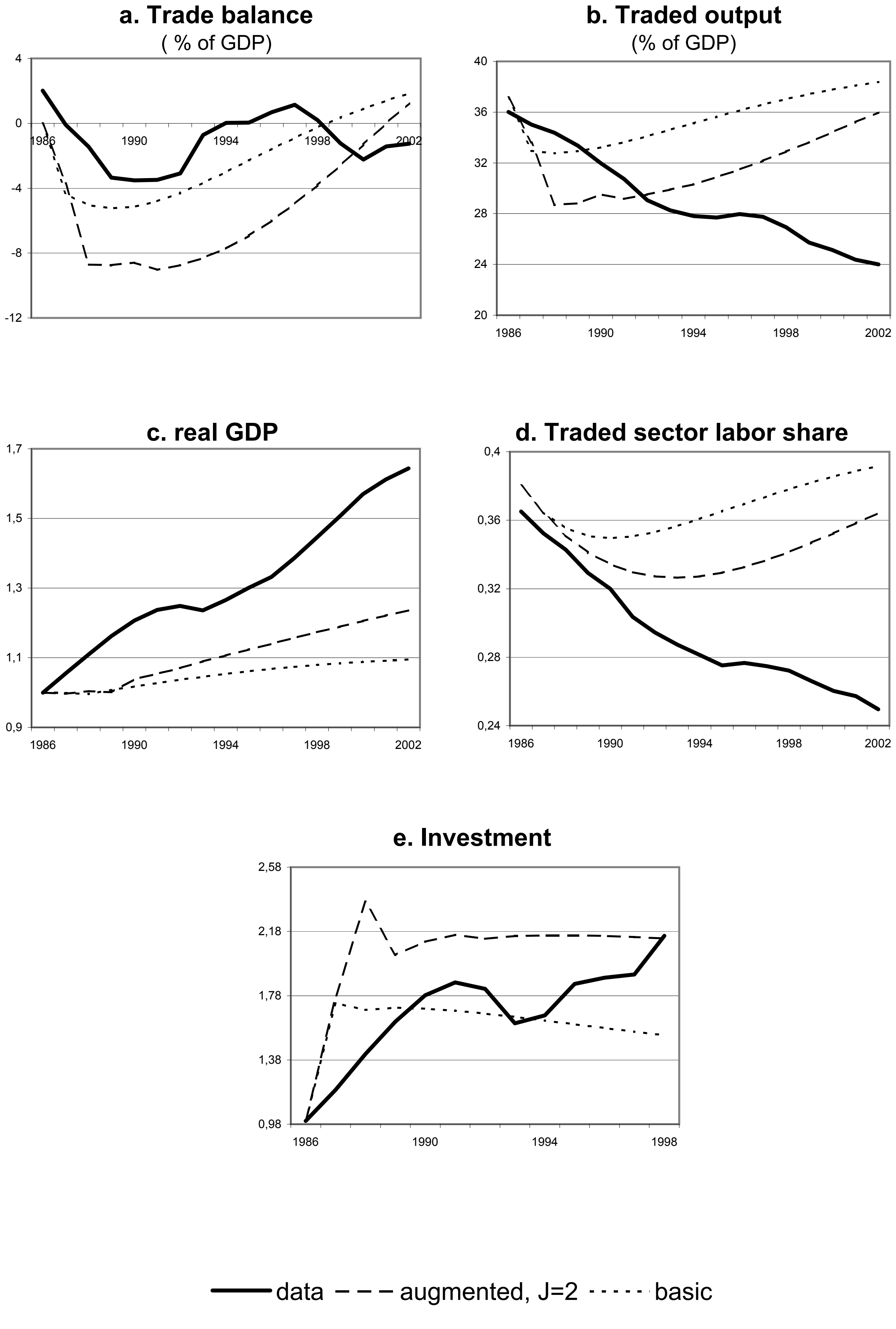


Figure 13. Comparison in the Price-Consumption dimension

(J=5 in augmented model)

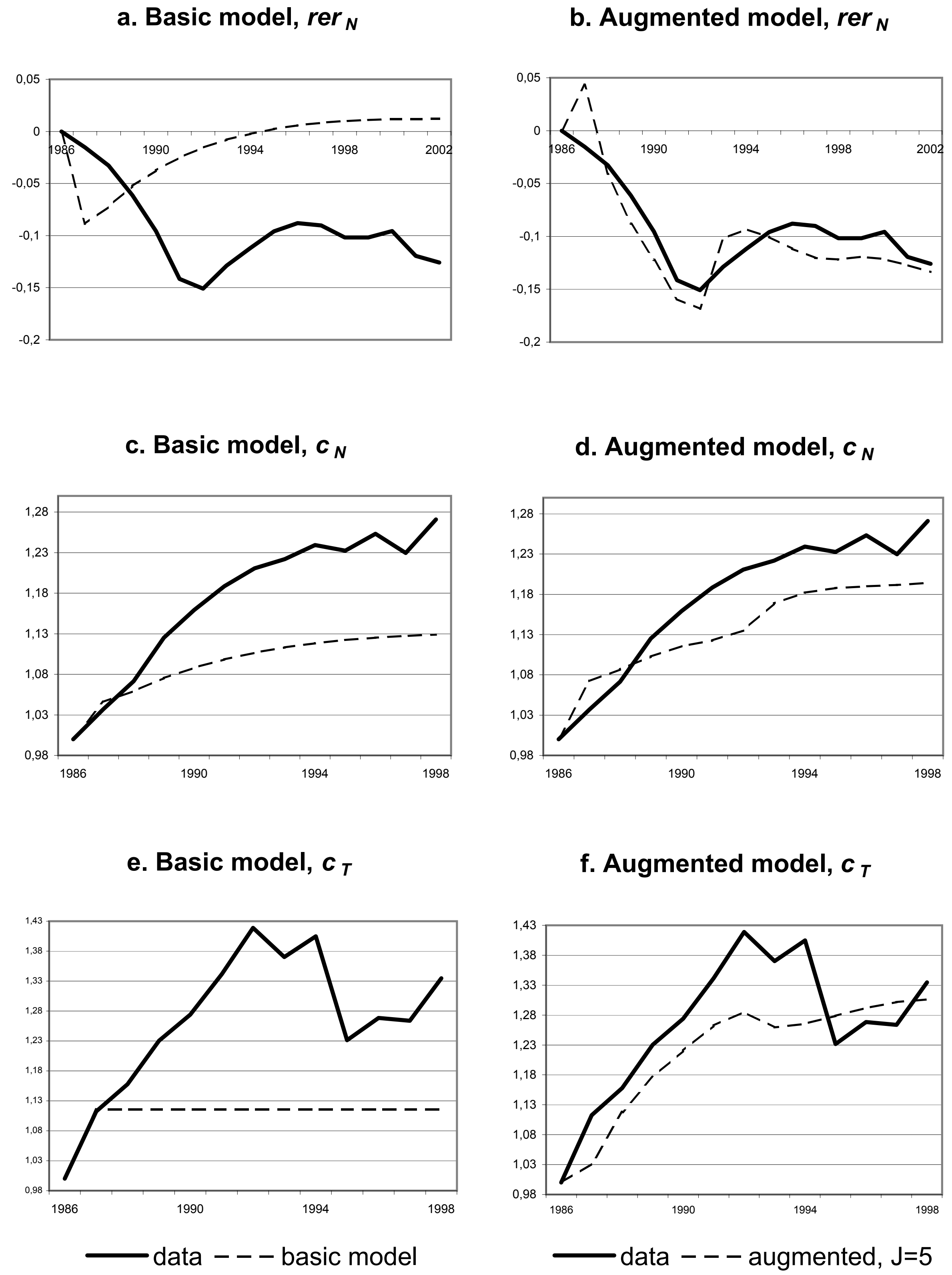


Figure 14. Comparison for other real variables
(J=5 in augmented model)

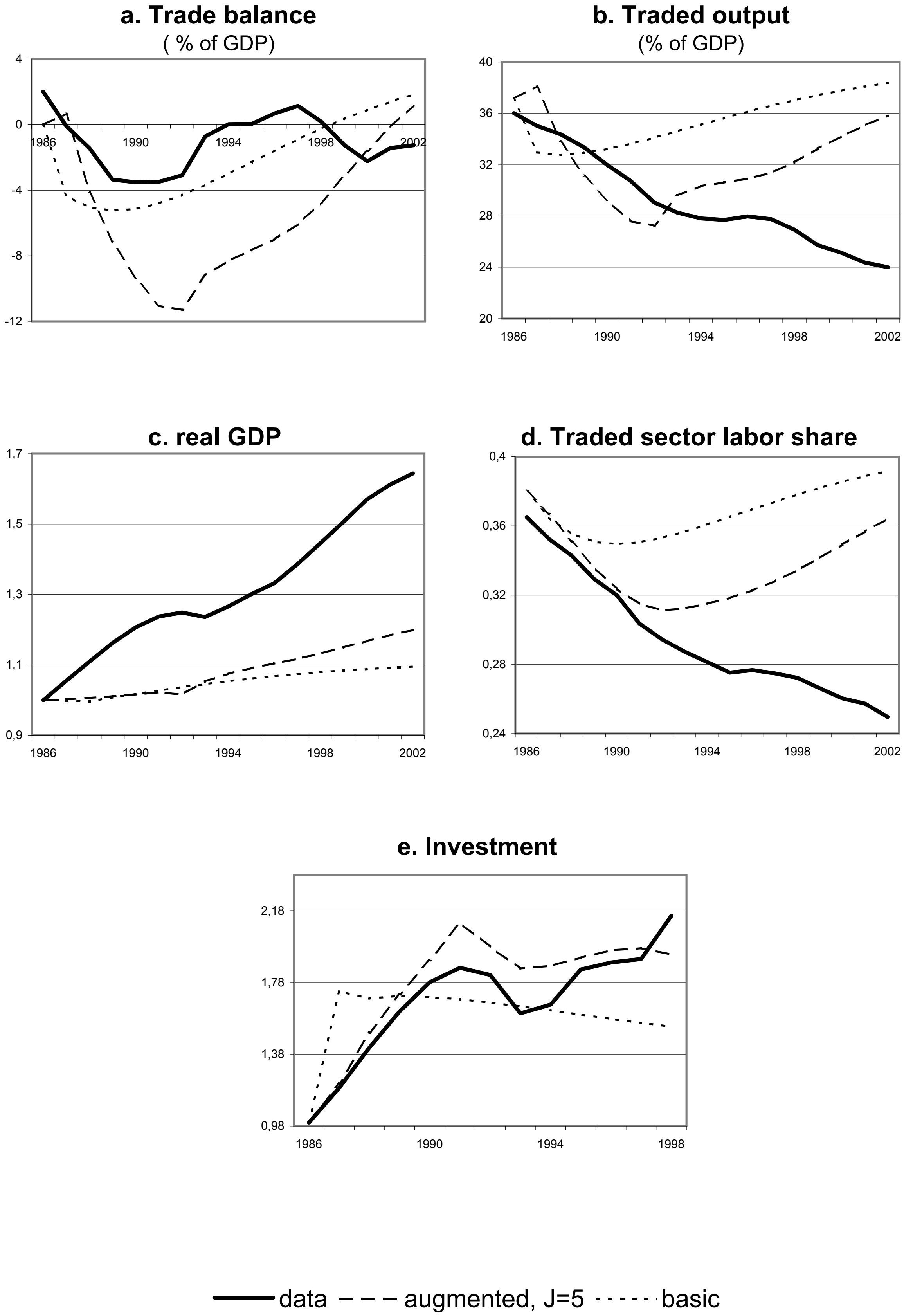


Figure 15. The effects of substituting convex capital frictions with time-to-build